Merging Teleseismic & Regional Model-Based Location Calibration in Western Eurasia, the Middle East, Northern Africa, and Europe using 3D Global Earth Models

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Most of the arrivals at the IDC are teleseismic. Moreover, the mislocation error due to a one-second error in the teleseismic travel times is more severe than that caused by a similar error in the regional travel time. Therefore, to significantly improve the locations, especially of moderate to large sized events, we need to calibrate the travel times of these teleseismic arrivals. We use a global 3-D crust and whole mantle model that we use to calibrate the travel time of P- and S-waves. To validate the model, we compare model predictions with empirical data that was not included in the model construction. Using a GT dataset of explosions and earthquakes, we carry out several relocation experiments. Using several lines of statistical evidence, we demonstrate that the teleseismic calibrations give us statistically significant improvement in event locations and error ellipses while maintaining 90% coverage.

The 3D model SP12 consists of the crustal model CRUST5.1 and the mantle model S&P12/WM13. S&P12/WM13 is a whole mantle model of P and S velocity obtained from a joint inversion of travel time and waveform data. The data used to construct this model consists of three-component waveforms separated into the body wave (cutoff period 45 s) and mantle wave (cutoff period 135 s) trains, in addition to P and PKP travel times from the ISC bulletin, and S, SS, SS-S, and ScS-S travel times derived from long-period waveforms. The model is expanded laterally in spherical harmonics up to degree 12 and radially in Chebyshev polynomials up to order 13. The inversion was performed using an existing S wave model (S12WM13) as the starting model and assuming that the P-velocity variations could be obtained with a scaling factor of 0.55. The scale length of the smallest structure resolved by this model is about 1500 – 2000 km. We have compared our model predicted travel times with the empirical HDC cluster path corrections (Engdahl and Bergman, 2001) to validate the model. The travel-time corrections correlate and a significant part of the 3-D variability in the empirical data is explained by the SP12 model.

We have used a perturbation theory based raytracer to compute the travel times through the SP12 model. The geometry of the raypaths are obtained using the global reference model PREM. For the travel time computations, we use a source depth of 10 km, which is the nominal depth of earthquakes in our test dataset. We compute the P- and S-times for distances between 25° and 97°, thereby reducing problems with phase mis-identification due to the upper mantle discontinuities and D?. We compute the travel times for the Group2 region with latitudes between 15°S and 80°N and longitudes between 40°W and 100°E. The travel time surfaces are sampled at every 2°X2° grid. A scaled-down version of the IDC error model is used as modeling error in the SSSCs.

We have relocated more than 1700 GT events (GT0-10) to demonstrate the location improvements in incorporating teleseismic calibrations. A global distribution of about 1500 stations is used for this test and includes more than 100,000 P arrivals and about 18,000 Pn arrivals. Preliminary results show that the locations of 67% of the events improve using P-arrivals only. Moreover, though our modeling errors are approximately 0.5 times the original IDC errors, the significantly reduced error ellipse achieves 90% coverage. Tests using a combination of calibrated and uncalibrated regional and teleseismic phases show that calibrated teleseismics improve locations over calibrated regionals alone.